NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

MEMORANDUM REPORT

for the

Air Technical Service Command, Army Air Forces

WIND-TUNNEL TESTS OF A 1/6-SCALE MODEL OF REPUBLIC

XF-12 VERTICAL TAIL INCORPORATING A DE-ICING

AIR DUCT

By Robert MacLachlan and Sadie M. Miller

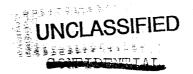Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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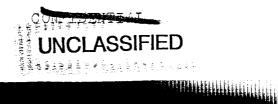
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SUMMARY

A 1/6-scale model of the Republic XF-12 vertical
tail with stub fuselage, stub horizontal tail, and a
de-icing air duct was tested in the Langley stability
tunnel. The investigation consisted of a study of the
effects of the duct, with and without air flow, on the
aerodynamic characteristics of the model.

The model tested was a revision of a model pre-
viously tested in the Langley stability tunnel. The
revised model differed from the original model in that
it incorporated a de-icing air duct, included a dorsal
fin, and had a larger stub fuselage. A comparison of
data obtained from tests of the original and revised
models was made.

The results of the investigation indicated that
the air duct had very little effect on the aerodynamic
characteristics of the model. A small change occurred
in the variation of rudder hinge-moment coefficient with
angle of attack but it is believed that this change can
be corrected by a properly applied spring tab.

INTRODUCTION

At the request of the Air Technical Service Command,
Army Air Forces, the 1/6-scale model of the Republic XF-12

vertical tail previously tested in the Langley stability tunnel (see reference 1) has been retested in a revised form. The revised model differed from the original model in that it incorporated a de-icing air duct, included a dorsal fin, and had a larger stub fuselage. The rudder internal balance plates of the model, however, were still offset; and in this way, the model still differed from the portion of the airplane which it represented.
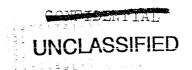
In the present report, data are included which show the effect of the air duct on the aerodynamic characteristics of the model. A comparison of data obtained from tests of the original and revised models is also included.

SYMBOLS

The coefficients and symbols used in this report are based on the same areas, spans, and chords as in reference 1 and are defined as follows:

C_L lift coefficient $\left(\dfrac{L}{qS}\right)$

C_{h_r} rudder hinge-moment coefficient $\left(\dfrac{H_r}{qb_r\overline{c}_r{}^2}\right)$

C_m pitching-moment coefficient $\left(\dfrac{M}{qc'S}\right)$

C_D drag coefficient $\left(\dfrac{D}{qS}\right)$

ΔP pressure coefficient across internal balance (pressure left of balance minus pressure right of balance divided by free-stream dynamic pressure).

E leakage factor $\left(1 - \dfrac{P_{(b)}-P_{(c)}}{P_{(a)}-P_{(d)}}\right)$

$P_{(b)}-P_{(c)}$ pressure difference across balance of internal balance

$P_{(a)}-P_{(d)}$ applied pressure difference across vents of internal balance

V air velocity, feet per second

L	lift of model, pounds
H_r	hinge moment of rudder; positive when tending to rotate the trailing edge to the left, foot-pounds
M	pitching moment of model about an axis parallel to and 9.125 inches ahead of rudder hinge line, foot-pounds
D	drag of model, pounds
S	area of vertical-tail model (above fuselage and excluding dorsal fin), square feet
c'	mean geometric chord of vertical-tail model (excluding dorsal fin), feet
$\bar{c}_r$	root mean square chord of rudder, feet
b_r	rudder span, feet
q	free-stream dynamic pressure, pounds per square foot
α	angle of attack of vertical tail (angle of yaw for airplane); positive when trailing edge is deflected to the left, degrees
δ_r	rudder angle relative to fin; positive when trailing edge is deflected to the left, degrees

APPARATUS AND MODEL

The 1/6-scale XF-12 vertical-tail model, which consists of the vertical tail, a stub fuselage, and a stub horizontal tail, was originally supplied and subsequently revised by the Republic Aviation Corporation. Figure 1 is a sketch in which the principle dimensions of the revised model are given. Two views of the revised model mounted horizontally in the 6- by 6-foot test section of the Langley stability tunnel are shown in figure 2.

With the exception of the de-icing air duct, the dorsal fin, and the increase in size of the stub fuselage, the

revised model is the same as the original model which is described in detail in reference 1. The changes made in the model by the addition of the doesal fin and the increase in size of the stub fuselage are shown in figure Details of the air duct are also shown in figure 1. To measure the velocity of the flow through the air duct, three total head and two static tubes were located in a plane perpendicular to the duct air stream and about half-way through the duct.

For the tests made on the revised model, only that section of the rudder located above the stub horizontal tail was utilized. No roughness strips were attached to the model and the tab was not deflected.
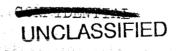
The model was supported entirely by the floating frame of the balance, so that all forces and moments acting on the model could be measured. The model was mounted in the center of the tunnel by projecting the model support through an opening in the tunnel wall. A fairing was installed around that part of the model support located inside the tunnel. A flexible seal was installed between the model support and the tunnel wall to prevent flow of air into the tunnel.

TESTS AND MEASUREMENTS

The model was tested with air duct open, sealed at exits, and sealed at entrance and exits. The tests consisted of angle-of-attack runs (angle of sideslip for airplane) for which α ranged from approximately $-18°$ to $18°$, and rudder-angle runs for which δ_r ranged from approximately $-25°$ to $6°$.

All tests were made at a dynamic pressure of 39.7 pounds per square foot. The corresponding airspeed under standard sea-level atmospheric conditions was 125 miles per hour, and the Reynolds number based on the mean geometric chord of the model was about 1,760,000.

Measurements of the lift, drag, and pitching moment of the model were obtained from the tunnel balances. Rudder hinge moments were measured by means of a spring torque balance linked to the rudder. Readings of the pressure differences across the balance in each of the three upper rudder internal-balance chambers and readings

of the total head and static pressures in the air duct
were taken. One of the static pressure tubes located
in the air duct did not function properly; therefore,
the air-duct velocity data presented herein were based
on the static pressure reading of one static tube.

The leakage factor E was measured for each of
the internal-balance chambers in the same manner as is
described in reference 2.

Jet-boundary corrections to the lift, rudder hinge
moment, pitching moment, drag, pressure difference across
balance, and angle-of-attack readings were the same as
those used in reference 1. No corrections were applied
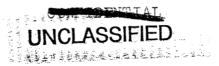for the effects of the model support and fairing.

RESULTS AND DISCUSSION

The results of the present investigation are given
in figures 3 to 6.

The average leakage factor E for all the balance
chambers was about 0.08 during all tests. This value is
greater than the value 0.01 found when the original model
was tested. Therefore, the internal-balance leakage must
have been slightly greater for the present tests. A more
complete discussion on leakage factor, including its effect
on flap hinge-moment coefficient, can be found in refer-
ence 2.

Tests were made to determine the aerodynamic character-
istics of the vertical tail with the de-icing air duct
open (fig. 3) and with the air-duct exits sealed (fig. 4).
The velocity through the open air duct reached a maximum
of about one-half free-stream velocity at $\alpha = 0^{\circ}$ and
decreased to zero at about $\pm 12^{\circ}$ angle of attack. (See
fig. 3(f).) The effect on the velocity through the duct
when rudder angle is increased was equivalent to a slight
decrease in angle of attack, the ratio being about 15°
rudder angle to 1° angle of attack.

The entrance to the air duct was located a short
distance above the stub fuselage in a section of the
leading edge of the vertical tail having about 50° sweep-
back. (See fig. 1.) It is likely, therefore, that the
air flow at the duct entrance was inclined toward the tip

of the vertical tail surface. Indication of inclination
of the air flow at the duct entrance was found in the
duct-pressure measurements which showed that the difference
at an angle of attack of zero between the total head in
the duct, when the duct exits were sealed, and the free-
stream static pressure was not equal to the free-stream
dynamic pressure (as it would have been for straight flow)
but to approximately 11/19 free-stream dynamic pressure.
When the air duct was open and $\alpha = 0^\circ$, the static pres-
sure inside the duct was slightly greater than free-stream
static pressure. This difference was probably the result
of the resistance of the duct to air flow. The inclination
of the air flow and the resistance of the duct to air flow
would account for the relatively low air velocity inside
the air duct compared with free-stream velocity.

A comparison of the results obtained for the model
with the air duct open and with the air duct sealed is
given in figure 5. When the air duct was sealed only at
the exits, the results obtained were very similar to those
found for the model when the duct was open. Before the
data for velocity through the air duct were computed, it
was thought, erroneously, that there was some leakage at
the duct exit allowing flow through the duct. Therefore,
tests were made with the air duct sealed not only at its
exits, but also at its entrance. By sealing the duct at
both its entrance and exits, results were obtained which
differed slightly from those found when the duct was open
and when the duct exits were closed. These differences
must have been the result of a change in flow originating
at the duct entrance when the duct entrance was sealed with
a strip of scotch tape.

The values of lift coefficient obtained for the
revised model were greater than those obtained for the
original model. (See fig. 6.) This increase in lift may
be attributed to the doesal fin and the increased size of
the stub fuselage on the revised model.

As shown in figure 6, the value for the variation
of rudder hinge-moment coefficient with α at small
values of α was negative for the revised model and
positive for the original model. The values for the two
models, however, did not differ by more than 0.001, a
difference which may be expected on any airplane and can
be corrected by a spring tab. If a spring tab is to be
used to correct for this difference, it is advised that a
negative increase in the basic value for the variation of

rudder hinge-moment coefficient with rudder angle be
effected (to at least -0.003 as explained in reference 3).
The variation of rudder hinge-moment coefficient with δ_r
at small angles of δ_r was about the same for both the
original and revised models. At large rudder angles, the
rudder hinge-moment coefficient was larger for the revised
model than for the original. This increase in C_{h_r} at
large angles of δ_r would make more critical the attain-
ment of desired pedal force and thus would affect the
estimations made in reference 1 of the characteristics of
the XF-12 airplane.

CONCLUSION

The results of the tests on the revised 1/6-scale
model of the XF-12 vertical tail indicated that the air
duct had very little effect on the aerodynamic character-
istics of the model. A small change occurred in the vari-
ation of rudder hinge-moment coefficient with angle of
attack but it is believed that this change can be corrected
by a properly applied spring tab.

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REFERENCES

1. MacLachlan, Robert: Wind-Tunnel Tests of a 1/6-Scale
   Model of Republic XF-12 Vertical Tail with Stub
   Fuselage and Stub Horizontal Tail. NACA MR No. L5E21,
   Army Air Forces, 1945.

2. Denaci, H. G.: Wind-Tunnel Tests of a 1/5-Scale Semi-
   span Model of the Republic XF-12 Horizontal Tail
   Surface. NACA MR No. L5D12, Army Air Forces, 1945.

3. Morgan, B. M., Bethwaite, C. F., and Nivison, J.:
   Spring-Tab Controls - Notes on Development to Date
   with Special Reference to Design Aspects. Rep.
   No. Aero. 1972, British R.A.E., Dec. 1944.
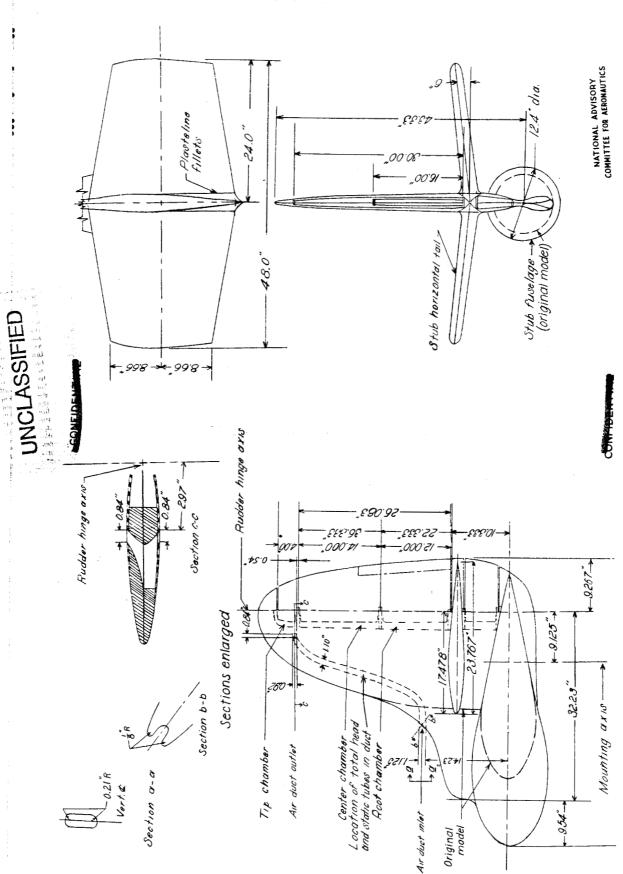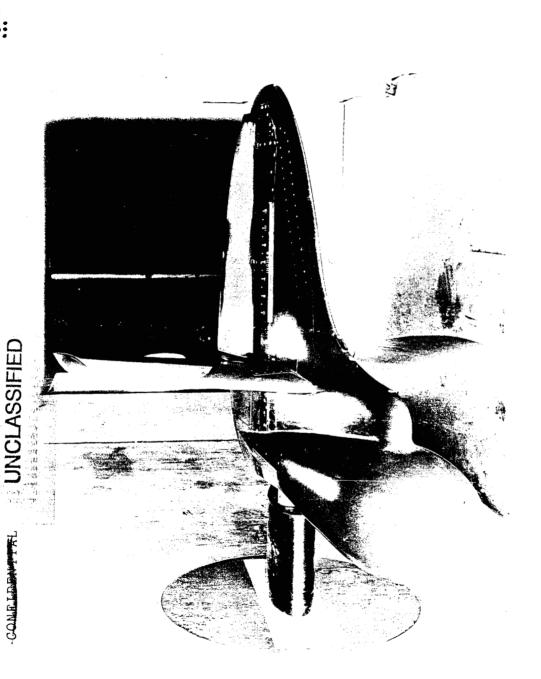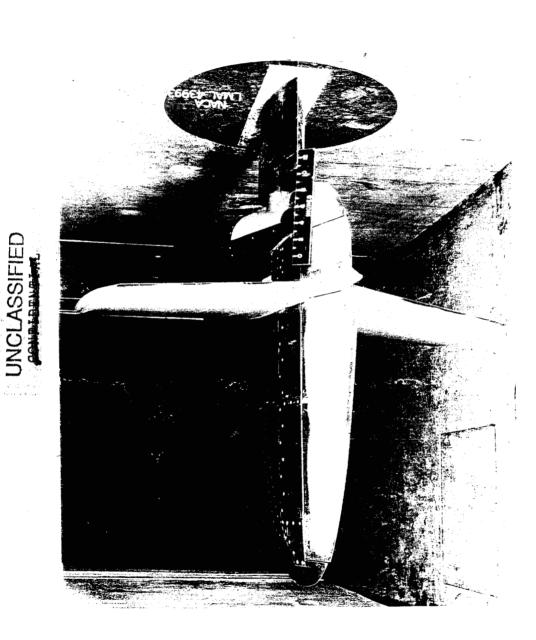
G18a

cale
b
. L5E21,

Semi-
il
1945.

Date
.

Plasteline fillets

24.0"

48.0"

8.66" — .998 → .998

43.33"

30.00"

16.00"

6.°

12.4" dia.

Stub horizontal tail

Stub fuselage (original model)

Rudder hinge axis

0.84"   0.84"

2.97"

Section c-c

Sections enlarged

Rudder hinge axis

0.21"R
Vert. ℄

Section a-a

⅛"R

Section b-b

26.063"

36.333"

14.000"

12.000"

22.333"

10.333"

.400"

0.54"

.84"

1.10"

.760

Tip chamber

Air duct outlet

Center chamber

Location of total head and static tubes in duct

Root chamber

Air duct inlet

Original model

6.°

1.125"

14.23"

17.478"

23.767"

9.267"

9.125"

32.23"

9.54"

Mounting axis

Figure 1.- Details of the revised 1/6 - scale model of the XF-12 vertical tail surface.

(a) Front view showing air duct entrance.

Figure 2.- The revised $\frac{1}{6}$-scale model of the XF-12 vertical tail mounted in the 6- by 6-foot test section of the Langley stability tunnel.

(b) Rear view showing one of two air duct exits.

Figure 2.- Concluded.

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(a) Lift coefficient.

Figure 3.- Aerodynamic characteristics of the XF-12 vertical tail model with de-icing air duct. Air duct open.

(b) Rudder hinge-moment coefficient.

Figure 3.- Continued.

(c) Pressure coefficient across balance.

Figure 3.- Continued.

(d) Drag coefficient.

Figure 3.- Continued.

(e) Pitching-moment coefficient.

Figure 3.- Continued.

(f) Ratio of velocity in air duct to free stream velocity.

Figure 3.- Concluded.

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Lift coefficient, C_L

δ_r
(deg)

5

0

-10

-20

-25

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1.2
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
-1.4

-20 -16 -12 -8 -4 0 4 8 12 16 20

Angle of attack, α, deg

(a) Lift coefficient.

Figure 4.- Aerodynamic characteristics of the XF-12 vertical tail model with de-icing air duct. Air duct sealed at exits.

(b) Rudder hinge-moment coefficient.

Figure 4 - Continued.

(c) Pressure coefficient across balance.

Figure 4.- Continued.

(d) Drag coefficient.

Figure 4.- Continued.

(e) Pitching-moment coefficient.

Figure 4.- Concluded.

(a) $\delta_r = 0°$.

Figure 5.- Effect of flow through de-icing air duct on aerodynamic characteristics of the revised XF-12 vertical tail model.

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Air duct

○ Open
□ Sealed at exits
◇ Sealed at exits and entrance

Pressure coefficient across the balance, ΔP

Tip chamber

Center chamber

Root chamber

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Angle of attack, α, deg

(a) Concluded.

Figure 5.- Continued.

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Air duct
○ Open
□ Sealed at exits
◇ Sealed at exits and entrance

Rudder hinge-moment coefficient, C_{hr}

Lift coefficient, C_L

Rudder angle, δ_r, deg

(b) $\alpha = 0°$.

Figure 5.— Continued.

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(b) Concluded.

Figure 5.- Concluded.

(a) $\delta_r = 0°$.

Figure 6.— Aerodynamic characteristics of the XF-12 vertical tail model as originally tested and as revised to incorporate de-icing air duct.

(b) $\alpha = 0°$.

Figure 6.- Concluded.